The Large Hadron electron Collider Detector Design Concept

A. Polini (for the LHeC Study Group)

Outline:

• Experiment requirements and accelerator boundaries (Physics, Machine, Interaction Region and Detector)
• Present Detector Design
• Future and Outlook
The LHeC at Poetic 2013

Mon 12:00 - Paul Laycock
“An Overview of the LHeC”

Tue 17:40 - Voica Radescu
“PDFs from the LHeC and the LHC search program”

Thu 10:00 – Vladimir Litvinenko:
“Energy Recovery Linac based LHeC”

Thu 13:20 - Alessandro Polini:
“The LHeC Detector Design Concept”

Fri 10:50 - Anna Stasto
“eA Physics with the LHeC”

Fri 13:15 - Pierre Van Mechelen
“Diffraction and forward Physics in ep collisions at the LHeC”

http://cern.ch/lhec

CDR: “A Large Hadron Electron Collider at CERN”
LHeC Study Group, arXiv:1206.2913
Kinematics & Motivation (60 GeV x 7 TeV ep)

\[ \sqrt{s} = 1.4 \text{ TeV} \]

- High mass \((M_{eq}, Q^2)\) frontier
- EW & Higgs
- \(Q^2\) lever-arm at moderate & high \(x\) \(\rightarrow\) PDFs
- Low \(x\) frontier \([x \text{ below } 10^{-6} \text{ at } Q^2 \sim 1 \text{ GeV}^2]\)

\(\rightarrow\) novel QCD

New physics, distance scales few \(10^{-20}\) m

High precision partons in LHC plateau

Large \(x\) partons

High Density Matter

Nuclear Structure & Low \(x\) Parton Dynamics

LHeC Experiment:

HERA Experiments:
- H1 and ZEUS

Fixed Target Experiments:
- NMC
- BCDMS
- E665
- SLAC

\(\frac{Q^2}{\text{GeV}^2}\)

\begin{align*}
10^6 &
10^5 \\
10^4 &
10^3 \\
10^2 &
10^1
\end{align*}

\begin{align*}
10^{-2} &
10^{-3} \\
10^{-4} &
10^{-5} \\
10^{-6} &
10^{-7}
\end{align*}
High x and high $Q^2$: few TeV HFS scattered forward:

- Need forward calorimeter of few TeV energy range down to $10^0$ and below
- Mandatory for charged currents where the outgoing electron is missing

Scattered electron:

- Need very bwd angle acceptance for accessing the low $Q^2$ and high y region.
Detector Design Approach

- Provide a baseline design which satisfies the Physics requirements along with the constraints from the machine and interaction region for running during the PHASE II of LHC

- Having to run along with the LHC, the detector needs to be designed and constructed in about 10 years from now to be able to run concurrently with the other LHC experiments designed for \textit{pp} and \textit{AA} studies in the \textit{ep/eA} mode, respectively.

- While avoiding large R&D programs, the final LHeC detector can profit from the technologies used nowadays at the LHC and the related developments and upgrades

- Modular and flexible design to accommodate with upgrade programs; Detector assembly above ground; Detector maintenance (shutdown)

- Affordable - comparatively reasonable cost.

- More refined studies are required and will follow with the TDR and once a LHeC collaboration has been founded
e± beam: two alternative designs

- **Ring-Ring**
  - e-p and e-A (A=Pb, Au, ) collisions
  - More “conventional” solution, like HERA, no difficulties of principle - at first sight - but constrained by existing LHC in tunnel
  - polarization 40% with realistic misalignment assumptions

- **Linac-Ring**
  - e-p and e-A (A=Pb, Au, ) collisions, polarized e- from source, somewhat less luminosity for e+
  - New collider type of this scale, Energy Recovery Linac
## Machine Parameters

<table>
<thead>
<tr>
<th></th>
<th>Ring-Ring Hi Lumi/Hi Acc</th>
<th>Linac-Ring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luminosity [$10^{33}$cm$^{-2}$s$^{-1}$]</td>
<td>1.3/0.7</td>
<td>1</td>
</tr>
<tr>
<td>Detector acceptance [deg]</td>
<td>10/1</td>
<td>1</td>
</tr>
<tr>
<td>Polarization [%]</td>
<td>40</td>
<td>90</td>
</tr>
<tr>
<td>IP beam sizes [$\mu$m]</td>
<td>30, 16</td>
<td>7</td>
</tr>
<tr>
<td>Crossing angle [mrad]</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>e- L* [m]</td>
<td>1.2/6.2</td>
<td>30</td>
</tr>
<tr>
<td>Proton L* [m]</td>
<td>23</td>
<td>15</td>
</tr>
<tr>
<td>e- beta$_{x,y}^*$ [m]</td>
<td>0.2,0.1/0.4,0.2</td>
<td>0.12</td>
</tr>
<tr>
<td>Proton beta$_{x,y}^*$ [m]</td>
<td>1.8, 0.5</td>
<td>0.1</td>
</tr>
<tr>
<td>Synchrotron power [kW]</td>
<td>33/51</td>
<td>10</td>
</tr>
</tbody>
</table>

R. Thomas et al. 2013
Linac Ring: Favored Option

Linac-Ring:

■ Reduced impact on the LHC schedule
■ New Accelerator Design (Energy Recovery Linac)
■ Dipole Field along the whole interaction region
■ LHC Interaction Point P2
The Interaction Region

- Optics compatible with LHC and $\beta^*=0.1\text{m}$
- Head-on collisions mandatory $\rightarrow$ High synchrotron radiation load, dipole in detector
- 3 beam interaction region
- Optimisation: High Luminosity-LHC uses IR2 quads to squeeze IR1 ("ATS" achromatic telescopic squeeze). Might improve further luminosity $[\sim 10^{34}\text{ cm}^{-2}\text{s}^{-1}]$
LR Interaction Region

Dipole Field along the full interaction region needed

B = ±0.3 Tesla for z = [−9m, +9m]

SR Fan growth with z

Linac-Ring Beampipe:

Inner Dimensions
Circular(x)=2.2cm; Elliptical(-x)=−10., y=2.2cm

Material: Be 2.5-3.0 mm wall thickness

Stress Test: Pipes would be sufficient to resist the external pressure

Note: 10 track passing 1.5 ~ 3.0mm thick Be wall - X/X₀=21% ~ 45% → R&D and/or move to composite beampipe
Beam Pipe Considerations

CDR Design:
- Beryllium 2.5-3 mm thickness
- Central beam pipe ~ 6 meters
- Constant x-section
- TiZrV NEG coated
- Periodic bakeout/NEG activation at ~220C (permanent system?)
- Wall protected from primary SR (upstream masks)
- Minimised end flanges, minimised supports

Additional manpower is necessary to advance on LHeC eng & vacuum physics issues
Detector: Requirements from Physics

- High resolution tracking system
  - excellent primary vertex resolution
  - resolution of secondary vertices down to small angles in forward direction for high x heavy flavor physics and searches
  - precise $p_t$ measurement matching to calorimeter signals (high granularity), calibrated and aligned to 1 mrad accuracy

- The calorimeters
  - electron energy to about 10%/ $\sqrt{E}$ calibrated using the kinematic peak and double angle method, to permille level
    Tagging of $\gamma$'s and backward scattered electrons - precise measurement of luminosity and photo-production physics
  - hadronic part 40%/ $\sqrt{E}$ calibrated with $p_{t_e}/p_{t_h}$ to 1% accuracy
  - Tagging of forward scattered proton, neutron and deuteron - diffractive and deuteron physics

- Muon system, very forward detectors, luminosity measurements
Dominant forward production of dense jets; backward measurements relaxed

**Central Pixel Tracker**
- 4 layer CPT
  - min-inner-R = 3.1 cm
  - max-inner-R = 10.9 cm
  - \( \Delta R = 15 \) cm

**Central Si Tracker**
- CST - \( \Delta R = 3.5 \) cm each
  - 1. layer: inner R = 21.2 cm
  - 2. layer: = 25.6 cm
  - 3. layer: = 31.2 cm
  - 4. layer: = 36.7 cm
  - 5. layer: = 42.7 cm

**Central Forward/Backward Tracker**
- 4 CFT/CBT
  - min-inner-R = 3.1 cm
  - max-inner-R = 10.9 cm

**Electromagnetic Calorimeter**
- Forward Si Tracker
  - FST - \( \Delta Z = 8. \) cm
  - min-inner-R = 3.1 cm; max-inner-R = 10.9 cm
  - outer R = 46.2 cm
  - Planes 1 - 5:
    - \( z_{5-1} = 370. / 330. / 265. / 190. / 130. \) cm

**Backward Si Tracker**
- BST - \( \Delta Z = 8. \) cm
  - min-inner-R = 3.1 cm; max-inner-R = 10.9 cm
  - outer R = 46.2 cm
  - Planes 1 - 3:
    - \( z_{1-3} = -130. / -170. / -200. \) cm

A. Polini

POETIC 2013, March 7th, Valparaiso, Chile
Tracker Simulation

LicToy  

\[ \frac{\Delta p_t}{p_t^2} \to 10^{-3} \text{GeV}^{-1} \]

- Silicon: compact design, low budget material, radiation hard

Impact parameter resolution \( \to 10\mu m \)
Detector of very compact design; It might be necessary to open places/grooves/tunnels for services affecting the aperture of the detector; Optimum between costs and detector acceptance needs to be found.

Service and Infrastructure need very careful design being the main contributor to Material Budget.
- Similar studies being done with FLUKA
- Most critical the forward region
- Rates far lower than LHC ($LHC \sim 5 \times 10^{14}$)
Tracker Detector Technology

- Choose among available technologies
  - $n$-$in$-$p$ (sLHC) or $n^+$$in$$n$ (ATLAS/CMS/LHCb)
- Radiation hardness in LHeC not as challenging as in LHC
- Silicon Pixel, Strixel, Strips
- Detailed simulation to best understand the needs and implications
- Readout/Trigger, Services, # silicon layers
- Analog/Digital Readout
- Modular structure for best replacement / maintenance and detector adoption: RR high luminosity / high acceptance running
- Pixel Detector*) (barrel CPT 1-4 and inner forward/backward FST/BST)
Same plots (left) and (small) deterioration in case of innermost barrel layer failure (right)
Solenoid Options

Large Coil
- Large Solenoid containing the Calorimeter
- 3.5 T Solenoid of similar to CMS/ILC
- Precise Muon measurement
- Large return flux either enclosed with Iron or Option of active B shielding with 2nd solenoid

Small Coil
- Smaller Solenoid placed between EMC and HAC
- Cheaper option
- Convenient displacement of Solenoid and Dipoles in same cold vacuum vessel (Linac-Ring only)
- Smaller return flux (less iron required)
- Muon $p$, $p_t$ measurement compromised
Magnets

Baseline Solution:

- Solenoid (3.5 T) + dual dipole 0.3 T (Linac-Ring Option)
- Magnets (may be) embedded into EMC LAr Cryogenic System

→ Need of study the Calorimeter Performance and impact of dead material between EMC and HAC sections; it might be possible placing the magnet system even in front of the EMC - at even lower radius at just outside of the tracking system
Baseline Detector
Electromagnetic Calorimeter (i)

- Baseline Electromagnetic Calorimeter
- LAr for barrel EMC calorimetry - ATLAS (~25-30 $X_0$)

- Advantage: same cryostat used for solenoid and dipoles
- GEANT4 simulation (*)
- Simulation results compatible with ATLAS
- Barrel cryostat being carefully optimized pre-sampler optimal
- 3 different granularity sections longitudinally

(*) F. Kocak, I. Tapan Uludag Univ.
- Simulation with simplified design w.r.t. Atlas
- LAr Calorimeter: good energy resolution, stable performance
- Simulation results compatible with ATLAS
- Warm (Pb/Sci) option also investigated
- $30X_0$ ($X_0(Pb)=0.56$ cm; 20 layers)
Hadronic Calorimeter (i)

- Baseline Design
  - HAC iron absorber (magnet return flux)
  - scintillating plates (similar to ATLAS TILE CAL)
  - Interaction Length: ~7-9 $\lambda_I$

- Setup:

<table>
<thead>
<tr>
<th>Tile Rows</th>
<th>Height of Tiles in Radial Direction</th>
<th>Scintillator Thickness</th>
</tr>
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<tbody>
<tr>
<td>1-3</td>
<td>97mm</td>
<td>3mm</td>
</tr>
<tr>
<td>4-6</td>
<td>127mm</td>
<td>3mm</td>
</tr>
<tr>
<td>7-11</td>
<td>147mm</td>
<td>3mm</td>
</tr>
</tbody>
</table>

- GEANT4 + FLUKA simulations
- performance optimization:
  - containment, resolution, combined HAC & EMC response
  - solenoid/dipoles/cryostat in between
- Preliminary studies of the impact of the magnet system on calorimetric measurements (GEANT4 & FLUKA *)
- Energy resolutions
- Shower profiles

Forward Energy and Acceptance

RAFGAP-3.2 (H. Jung et al. - http://www.desy.de/~jung/rapgap.html)
HzTool-4.2 (H. Jung et al. - http://projects.hepforge.org/hztool/)
selection: \( q^2 > 5 \)

\( \text{RAD: } 60 \text{ GeV electron x 7 TeV proton} \)

\( \text{CHARM: } 60 \text{ GeV electron x 7 TeV proton} \)

\( \text{DIFF: } 60 \text{ GeV electron x 7 TeV proton} \)

\( \text{NRAD: } 60 \text{ GeV electron x 7 TeV proton} \)

\( \text{Jet Energy [GeV]} \)

\( \text{Highest acceptance desirable} \)
Forward/Backward Calorimeters

**Forward FEC + FHC:**
- tungsten high granularity
- Si (rad-hard)
- high energy jet resolution
- FEC: \( \sim 30X_0 \); FHC: \( \sim 8-10 \lambda_l \)

**Backward BEC + BHC:**
- need precise electron tagging
- Si-Pb, Si-Fe/Cu (\( \sim 25X_0 \), 6-8 \( \lambda_l \))

**GEANT4 simulation** *
- containment, multi-track resolution (forward)
- \( e^\pm \) tagging/E measurement (backwards)

* A. Kilic, I. Tapan - Uludag University
Forward/Backward Calorimeters (ii)

- Highest energies in forward region
- Radiation hard
- High Granularity
- Linearity

<table>
<thead>
<tr>
<th>Calorimeter Module</th>
<th>Layer</th>
<th>Absorber</th>
<th>Thickness</th>
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<tbody>
<tr>
<td>FEC(W-Si) 30x0</td>
<td>1-25</td>
<td>1.4 mm</td>
<td>16 cm</td>
</tr>
<tr>
<td></td>
<td>26-50</td>
<td>2.8 mm</td>
<td>19.5 cm</td>
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<tr>
<td></td>
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<td></td>
<td>5 mm</td>
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<td>35.5 cm</td>
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<tr>
<td>FHC (W-Si)</td>
<td>1-15</td>
<td>1.2 cm</td>
<td>39 cm</td>
</tr>
<tr>
<td></td>
<td>16-31</td>
<td>1.6 cm</td>
<td>48 cm</td>
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<td></td>
<td>32-46</td>
<td>3.8 cm</td>
<td>78 cm</td>
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<td>14 mm</td>
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<td></td>
<td></td>
<td></td>
<td>165 cm</td>
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<tr>
<td>FHC (Cu-Si)</td>
<td>1-10</td>
<td>2.5 cm</td>
<td>30 cm</td>
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<tr>
<td></td>
<td>11-20</td>
<td>5 cm</td>
<td>55 cm</td>
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<tr>
<td></td>
<td>21-30</td>
<td>7.5 cm</td>
<td>80 cm</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td>5 mm</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>165 cm</td>
</tr>
<tr>
<td>BEC (Pb-Si)</td>
<td>1-25</td>
<td>1.8 mm</td>
<td>17 cm</td>
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<tr>
<td></td>
<td>26-50</td>
<td>3.8 mm</td>
<td>22 cm</td>
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<tr>
<td></td>
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<td>5 mm</td>
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<td>39 cm</td>
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<tr>
<td>BHC(Cu-Si) 7.9</td>
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<td>39.75 cm</td>
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<td>16-27</td>
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<td>49.8 cm</td>
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<td></td>
<td>28-39</td>
<td>4.0 cm</td>
<td>55.8 cm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6.5 mm</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>145.35 cm</td>
</tr>
</tbody>
</table>

**Electromagnetic Response**

- $\text{FEC} (W-Si)$
  $\sigma_E/E = (14.0 \pm 0.16)\% \oplus (5.3 \pm 0.049)\%$
  $\sigma_E/E = (11.4 \pm 0.5)\% \oplus (6.3 \pm 0.1)\%$

**Hadronic Response**

- $\text{FEC} (W-Si) \& \text{FHC} (W-Si)$
  $\sigma_E/E = (45.4 \pm 1.7)\% \oplus (4.8 \pm 0.086)\%$
- $\text{FEC} (W-Si) \& \text{FHC} (Cu-Si)$
  $\sigma_E/E = (46.0 \pm 1.7)\% \oplus (6.1 \pm 0.073)\%$
- $\text{BEC} (Pb-Si) \& \text{BHC} (Cu-Si)$
  $\sigma_E/E = (21.6 \pm 1.9)\% \oplus (9.7 \pm 0.4)\%$

A. Polini
Baseline Solution:

- Muon system providing tagging, no independent momentum measurement
- Momentum measurement done in combination with inner tracking
- Present technologies in use in LHC exp. sufficient (RPC, TGC, MDT)
Muon System Extensions

Extensions:
- Independent momentum measurement
- Large solenoid (incompatible with LR dipoles)
- Dual Coil System (homogeneous return field)
- Forward Toroid System
LHeC Detector installation (i)

LHeC Detector assembly on surface

- The strategy proposed is to complete as much as possible the assembly of the detector on surface. The detector has been split in the following main parts:

  1) Coil cryostat, including the superconducting coil, the two dipoles and eventually the EMCal, if the LAr version is retained.

  2) Three barrel wheels and two endcaps HCal tile calorimeter, fully instrumented and cabled.

  3) Two HCal inserts, forward and backward.

- The maximum weight of a single element to be lowered from surface to underground has been limited to 300 tons, in order to make possible the lowering by renting a standard crane, as already applied by L3 for its barrel HCal. The superconducting coil and the two integrated dipoles will be tested at nominal current on surface, whilst the field mapping will be performed underground.
LHeC Detector Installation (ii)

- The assembly on surface of the main detector elements as approximately 16 months.
- The Coil system commissioning on site three additional month, preparation for lowering one month and lowering one week per piece.
- Underground completion of the integration of the main detector elements inside the L3 Magnet would require about two months, cabling and connection to services.
- Some six months, in parallel with the installation of Muons Tracker and the EMCal.
- The total estimated time is thus 30 months.
- The field map would take one extra month.
- Some contingency is foreseen between the integration inside the L3 Magnet of the same elements (2 months).
- Tight but doable.

A. Herve, A. Gaddi - LHeC Chavannes 2012
Outer Detectors

Present dimensions: LxD = 14x9m² [CMS 21 x 15m², ATLAS 45 x 25 m²]

Electron outgoing direction:
- Tag photo-production (Q2~0), Luminosity Detectors, Electron Taggers

Proton/Ion outgoing direction: Very forward nucleons
- Zero Degree Calorimeter, Forward Proton Spectrometer

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Luminosity measurement: physics processes

Bethe-Heitler (collinear emission):
- very high rate of ‘zero angle’ photons and electrons, but sensitive to the details of beam optics at IP
- requires precise knowledge of geometrical acceptance
- suffers from synchrotron radiation
- aperture limitation
- pile-up

QED Compton (wide angle bremsstrahlung):
- lower rate, but
- stable and well known acceptance of central detector

Methods are complementary, different systematics

**NC DIS** in \((x,Q^2)\) range where \(F_2\) is known to \(O(1\%)\) for relative normalisation and mid-term yield control

\[(\sigma_{\text{vis}}^{\text{DIS, } Q^2>10\text{GeV}^2} \sim 10\text{nb for } 10^\circ \text{ and } \sim 150\text{nb for } 1^\circ \text{ setup})\]
Luminosity measurement: Bethe-Heitler (ep → eγp)

For LR option (zero crossing angle) the photons travel along the proton beam direction and can be detected at z≈-120m, after the proton bending dipole.

→ Place the photon detector in the median plane next to interacting proton beam

Main limitation – geometrical acceptance, defined by the aperture of Q1-Q3. May be need to split dipole D1 to provide escape path for photons.

Geometrical acceptance of 95% is possible, total luminosity error δL≈1%.

- clarify p-beamline aperture in the range z=0-120m
- need to calculate acceptance and its variations due to beam optics; (but this is essentially HERA setup, so we can use similar detectors/methods)
Electron Tagger

Detect scattered electron from Bethe-Heitler (also good for photoproduction physics and for control of $\gamma p$ background to DIS)

Clean sample – background from e-gas can be estimated using pilot bunches.

Three possible positions simulated $\Rightarrow$ acceptances reasonable (up to $20\div25\%$)

62m is preferable – less SR, more space available.

Next steps: detailed calculation of acceptance and variations due to optics (beam-tilt, trajectory offset) and e-tagger position measurement and stability

Need a precise monitoring of beam optics and accurate position measurement of the e-tagger to control geometrical acceptance to a sufficient precision (e.g. 20mm instability in the horizontal trajectory offset at IP leads to 5% systematic uncertainty in the $\sigma_{\text{vis}}$)

Main experimental difficulty would be good absolute calibration and resolution (leakage over the detector boundary)
Luminosity measurement: QED Compton

electron and photon measured in the main detector (backward calorimeter)

$\sigma_{\text{vis}} \sim 3.5 \text{nb (low } Q^2 \text{ setup)}; 0.03 \text{nb (high } Q^2 \text{ setup)}$

Install additional ‘QEDC tagger’ at $z \approx -6 \text{m} \rightarrow \text{increase visible cross section for QEDC up to } \sim 3-4 \text{ nb}$

$\rightarrow$ e.g. two moveable sections approaching the beam-pipe from top and bottom (assume angular acceptance $\theta \approx 0.5 \div 1^\circ$)

Detector requirements:

- good position measurement, resolution, alignment for the movable sections of QEDC tagger
- good energy resolution, linearity in 10-60 GeV range
- small amount of dead material in front (and well known/simulated)
- efficient e/\gamma separation $\rightarrow$ a small silicon tracker in front of calorimeter modules (this also allows z-vertex determination)
Zero Degree Calorimeter

- The position of ZDC in the tunnel and the overall dimensions depend mainly on the space available for installation (~90mm space between two beampipes at z~ 100m)

→ need detailed info/simulation of beam-line

- One can consider also the ZDC for the measurement of spectator protons from eD or eA scattering (positioned external to proton beam as done for ALICE)
Zero Degree Calorimeter for the LHeC

Minimization of material in front of ZDCs
- Possible thin window for spectator protons
- No flanges at the recombination chamber
- Optimization of the design of the vacuum supports

95 mm between beam pipes
- ZN (movable)
- Bakeout system

Thin window?
Recombination chamber
Space for machine luminosity monitor

ALICE ZDC
Forward Proton Detection

\[ \text{ep} \rightarrow \text{eXp’} \text{ diffractive scattering} \]
(proton survives a collision and scatters at a low angle along the beam-line)

\[ \xi \approx 1 - \text{Ep’}/\text{Ep} \sim 1\% \]

The feasibility to install forward proton detectors along the LHC beamline investigated at the ATLAS and CMS

→ the results of R&D studies are relevant for LHeC
Acceptance for Forward Protons

- Scattered protons are separated in space from the nominal beam: \( x_{\text{offset}} = D_x \times \xi \); \( D_x \) - energy dispersion function.

- Acceptance window is determined by the closest approach of proton detectors to the beam, and by the size of beam-pipe walls.

- Assume closest approach \( 12\sigma_{\text{beam}} \) (\( \sigma_{\text{beam}} = 250\mu\text{m at 420m} \)), \( R_{\text{beampipe}} \approx 2\text{cm} \), \( D_x \approx 1.5\text{m} \).

![Detector acceptance diagram](image)
Summary and Outlook

Status

- A LHeC baseline detector concept has been worked out.
- The design depends heavily on the constraints from the machine and interaction region.
- For all cases a feasible and affordable concept which fulfills the physics requirements has been presented.
- As a baseline many improvements available. A more precise design will follow from more detailed simulations, engineering and the knowledge of the machine constraints.

The Future

- Start a new phase in detector design.
- A complete software simulation environment needed.
- Collect people, experience, information.
- Identify and address critical items, discuss the timeline for realization.
- Build a collaboration and move next steps towards a Technical Design.